第 44 卷第 5 期
2015 年 5 月

光 子 学 报
ACTA PHOTONICA SINICA

Vol. 44 No. 5
May 2015

doi:10.3788/gzxb20154405.0523002

一种基于级联半导体光放大器环镜的光串并转换器

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摘　要:为了实现高速光信号的降速处理,提出了一种基于级联半导体光放大器环镜(SLALOM)的光串并转换器,用于实现将高速串行光脉冲信号转换成低速并行光脉冲信号.该光串并转换器采用串联SLALOM组成,将前一级SLALOM的输出作为后一级SLALOM的输入;SLALOM之间的光传播时延为输入光信号比特周期;设置控制光与信号光脉冲时序,实现各级SLALOM光脉冲并行输出.通过采用1×10光串并转换器实现将80 Gb/s串行信号转换为10路8 Gb/s并行信号,并对控制、信号脉冲光功率和时间偏移量器件参量进行了优化.对于1×10光串并转换器,端口接收灵敏度差异小于10 dB.该光串并转换器光功率损耗小、易于扩展并行端口数目,可用于光通信领域中的高速解复用、光信号处理和光交换系统中.

关键词:串并转换;半导体光放大器环镜;光纤通信;解复用;光信号处理

中图分类号:TN929.11;TN248.4;TN722　**文献标识码**:A　**文章编号**:1004-4213(2015)05-0523002-5

All-Optical Serial-to-Parallel Converter based on Semiconductor Laser Amplifer in Loop Mirrors

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Abstract: In order to reduce the bitrate of high-speed optical signal, a novel all-optical serial-to-parallel converter is proposed, which is based on the cascaded Semiconductor Laser Amplifier in a Loop Mirror (SLALOM), to be used to convert high speed serial optical signal to multi-output low-speed parallel optical signal. The converter adopts the structure of the cascaded SLALOMs, the output of the previous SLALOM connects to the input of the next one with the optical propagation delay time between them equaling to the bit period of the input optical pulse signal. Morever, the particular timing of optical control and signal pulses is designed to guarantee appropriate outputs. The feasibility is verified by converting 80 Gb/s serial optical signal to ten 8 Gb/s parallel outputs by using the designed 1×10 all-optical serial-to-parallel converter. The device parameters are optimized including the optical power of control / signal pulse and the time offset of them. The difference of the receive sensitivity values of all output ports is less than 10 dB. Comparing with the traditional parrallel structure, the proposed converter has the advantage of lower optical power loss, and it′s easier to extend parallel port numbers, which is available for the applications including high-speed demultiplexing, optical information processing

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Foundation item: The Young Scientist Fund of NSFC (No. 61101095), the National High Technology Research and Development Program of China (No. 2013AA014402) and the Science Research Fund of Southwest Petroleum University (No. 2012XJZ022)

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Received: Dec. 4, 2014; **Accepted**: Feb. 10, 2015

and optical switching system.

Key words: Serial-to-parallel conversion; Semiconductor laser amplifier in a loop mirror; Optical fiber communication; Demultiplexing; Optical signal processing

OCIS Codes: 230.4480; 060.4510; 250.5980

0 Introduction

The All-Optical Serial-To-Parallel Converter (AOSPC) converts high speed serial optical signal[1-3] to multi-output slow parallel optical signal directly in optical domain, and it's a key device for optical signal processing and optical switching. Several AOSPC schemes have been proposed by using various structures and technologies[4-9]. One time-to-wavelength mapping strategy using cross-Phase Modulation (XPM) effect in the Highly Nonlinear Fiber (HNLF) has realized 40Gb/s to 4 × 10Gb/s serial to parallel conversion[10]. However, it requires the complex chirp control and is incompatible with the WDM application. Similarly, another time-to-wavelength mapping strategy using cross-Gain Modulation (XGM) effect in Semiconductor Optical Amplifier (SOA) has realized 40Gb/s to 16×2.5 Gb/s serial to parallel conversion[11]. However, its Suppression Ratio (SR) is limited by XGM performance and the scalability of the port number leads to the increase of the spectral width. The structure of Mach-Zehnder Delay Interferometers (MZDIs) with the particular phase operation has been fabricated for 8 bit processing at 40 Gb/s[12], but 1-bit preamble pulse with $\pi/2$ phase needs to be inserted for each conversion period. In this paper, one novel AOSPC based on the cascaded semiconductor Laser Amplifier In A Loop Mirrors (SLALOMs) is provided.

1 The structure and principle

The structure of the proposed AOSPC is illustrated in Fig. 1. For an N-bit AOSPC, N SLALOMs are cascaded by optical circulators and optical delay lines between them. The serial signal is input to the first optical circulator and the parallel outputs consist of each SLALOM outputs. Each SLALOM is controlled by the same optical control pulses which are distributed to each control port by using 1 × N optical splitter. SLALOM consists of a SOA, a 2×23 dB optical coupler and two Wavelength Division Multiplexer (WDM), where the SOA locates with an offset from the middle of the SLALOM ring[13-16].

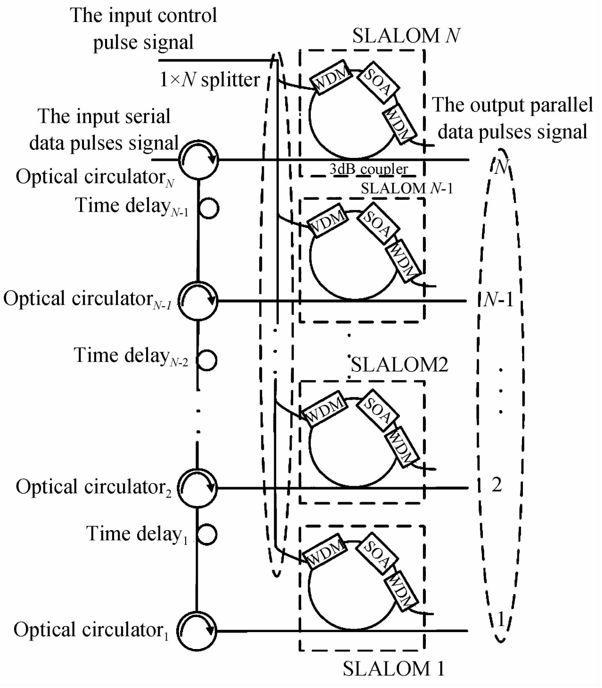


Fig. 1 The structure of the proposed AOSPC

For a single SLALOM, the output window is opened or closed rapidly depending on the existence of the optical control pulse. In the absence of it, the input signal is totally reflected back to the input port. On the contrary, the signal is passed to the output port. The particular timing relationship of the input / output optical signal and the optical control pulses in the proposed scheme is illustrated in Fig. 2. Defining the duration of N-bits parallel output signal as one period, the optical control pulses are synchronized with the last bits in each period. Due to the absence of the optical control pulses, the input signal from the 1st to (N-1) th bits in one period are reflected by the SLALOMs to the next ones continuously. The reflected signal moves forward along the cascaded SLALOMs through the optical circulators. The delay time between the adjacent SLAOMs, i. e. the sum of the propagation time of both one SLALOM and one optical delay line, equals to the bit period of input signal, which means the neighbor bits appear at the adjacent SLALOMs at the same time. Until the last bit and the optical control pulse arrive simultaneously, each bit in one period reaches the respective SLALOM and is parallel output by the optical control pulse.

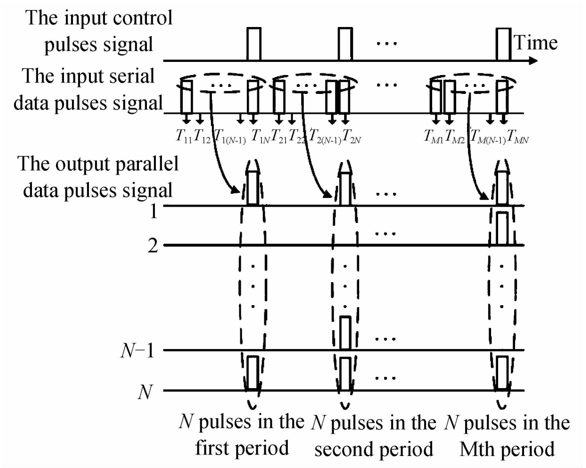


Fig. 2 The timing relationship of input, output and control signal

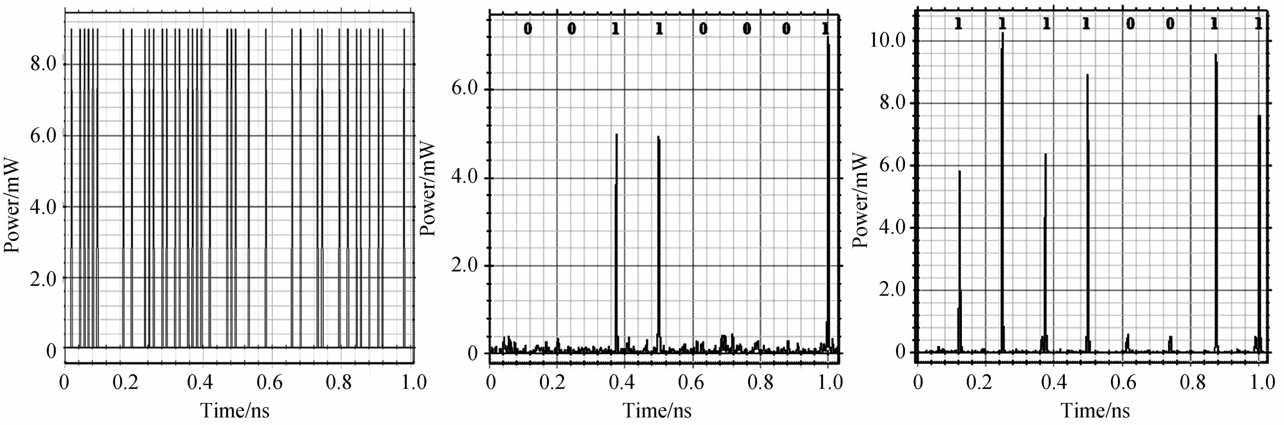
2 Results and discussions

For verifying the feasibility of the scheme, the simulation experiments have been performed in the professional design platform, OptiSystem. One 1×10 AOSPC based on SLALOMs is established for converting 80Gb/s RZ serial optical signal to ten 8Gb/s parallel outputs. The main adopted parameters are shown in Table 1.

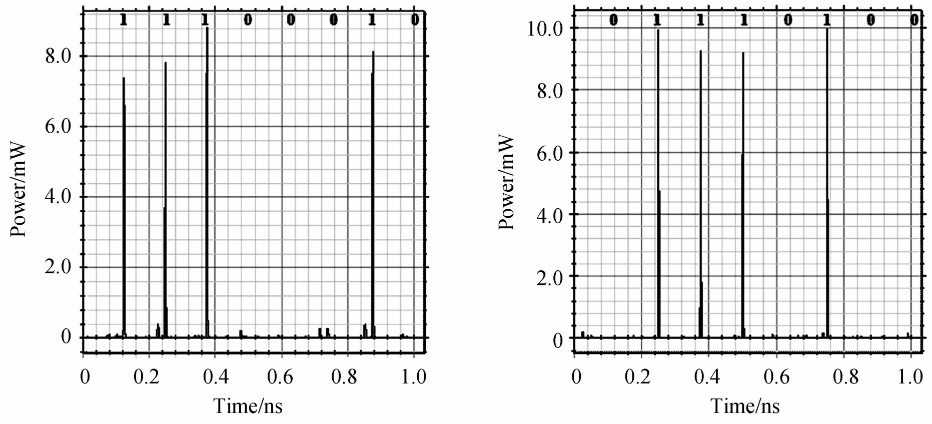
Table 1 List of parameters

Parameter	Value
Signal light wavelength	1 550 nm
Control light wavelength	1 579 nm
Peak optical power of the signal pulses	9 mW
Peak optical power of the control pulses	300 mW
Signal pulse width (FWHM)	3 ps
Control pulse width (FWHM)	1 ps
Injection current of SOA	200 mA
The time offset of SOA in the SLALOM	0.5 ps
Optical confinement factor	0.45
Active length of SOA	0.5 mm
Active width of SOA	0.4 μm
Active height of SOA	0.4 μm
Recombination coefficient A	$1.0\times10^{8}\ \mathrm{s}^{-1}$
Recombination coefficient B	$5.6\times10^{-15}\ \mathrm{m}^{3}\mathrm{s}^{-1}$
Recombination coefficient C	$3\times10^{-42}\ \mathrm{m}^{6}\mathrm{s}^{-1}$

For simplicity, only a small section of input and output waveforms is extracted. The input serial signal is shown in Fig. 3(a), whose binary values are "0101111100 0001010011 1011011011 1101000111 0010001000 0010100011 0001010110 1011000010". The 1st, 4th, 6th, 10th parallel output signals are

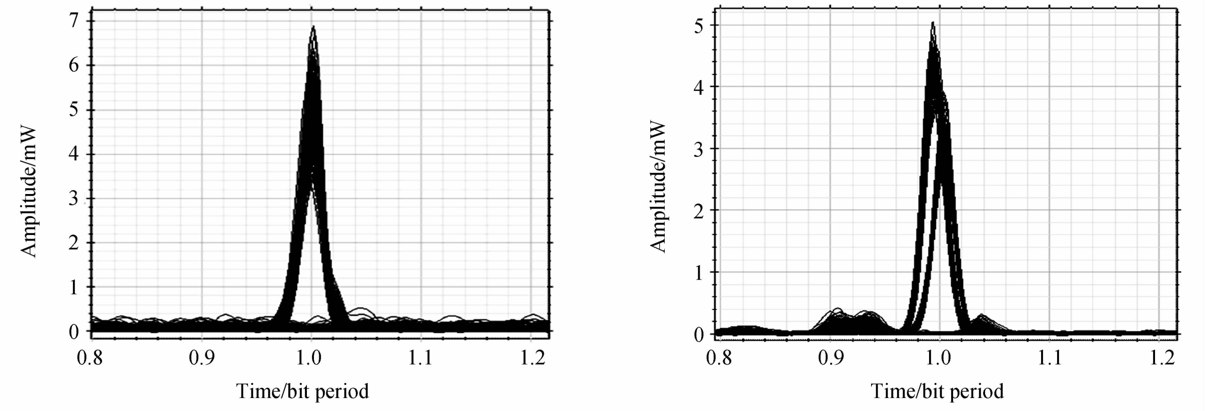


(a) The input serial signal (b) The 1st output signals (c) The 4th output signals

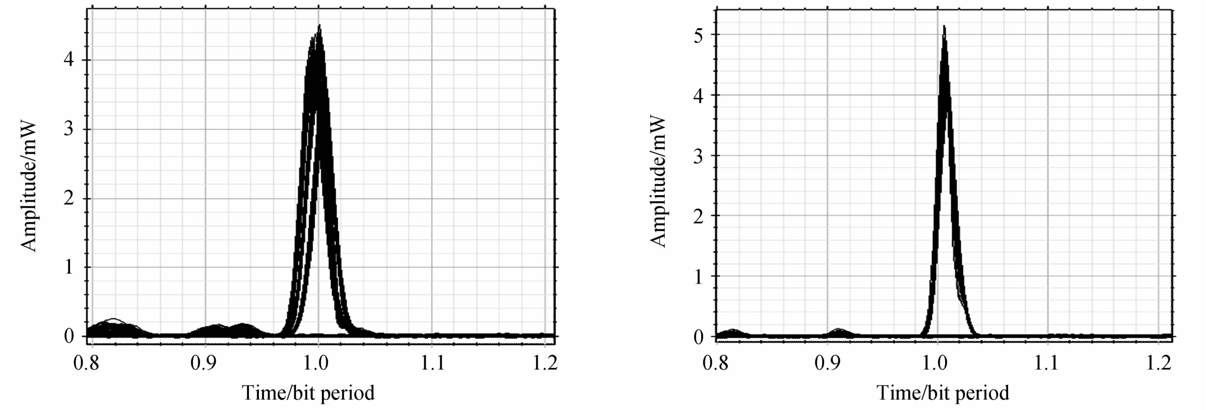


(d) The 6th output signals (e) The 10th output signals

Fig. 3 The input serial signal and the output signals

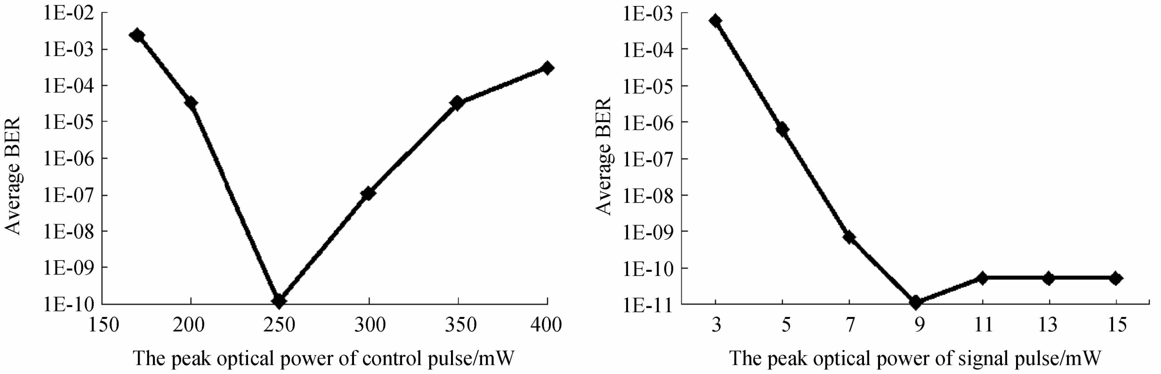


(a) The 1st output signals (b) The 4th output signals

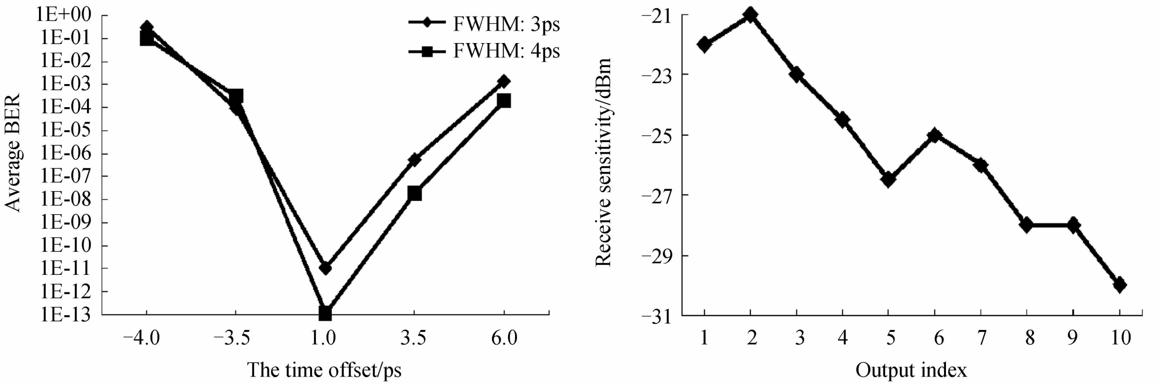


(c) The 6th output signals (d) The 10th output signals

Fig. 4 The eye diagrams of the output signals



(a) The impacts of the peak power of the control pulses (b) The impacts of the peak power of the signal pulses



(c) The impacts of the peak power of the time offset (d) The receive sensitivity of each parallel output signal

Fig. 5 The impacts of different parameters shown respectively in Fig. 3 (b) ～ (e), whose corresponding binary values shown in the inserts verify the correct serial-to-parallel conversion. The eye diagrams in Fig. 4 indicate that the eye openings of each output are acceptable but different from each other. The min SR is 10 dB and its Q factor is 6. 6. The signal becomes worse with the decrease of the output port index. For example, the eye opening of the 1st output is smaller than the 10th output. The same result appears again in Fig. 5(d) and the reason is explained later.

The optimization of the system parameters is also investigated. The relationship of the average BER and the peak optical power of the control pulse is shown in Fig. 5(a). There exists an optimum power value since higher control optical power causes severe pattern effects on the output signal due to the gain saturation in the SOA and lower power degrades the opening window of SLALOM.

As shown in Fig. 5 (b), the average BER is reduced with the increase of signal optical power, which is due to that the SOAs′ ASE noise is suppressed lower when the signal optical power becomes higher.

The time offset between the centers of the control and signal pulses injected into the SLALOM determines the height and width of opening window. A certain delay of the control pulse relative to the signal pulse benefits to achieve the lowest BER as shown in Fig. 5 (c), where the FWHM of the signal pulses are 3 ps and 4 ps.

Fig. 5(d) shows the receive sensitivity at the BER of 10^{-9} for each parallel output signal. The small-index output ports, which experience more SLALOMs according to the structure in Fig. 1, have worse performance than the high-index output ports due to the signal degradation caused by the SLALOMs. So the higher-index output ports have lower BER than the small-index ones. The difference of the receive sensitivity values of all output ports is less than 10dB for the 1×10 AOSPC.

By comparison, the proposed scheme has a better performance. The Q factors of the four output signals are within the range from 6. 2 to 7. 6 in the time-to-wavelength mapping scheme[10], Whereas they reach 6. 6 here. The max suppression ratio is 7. 1 dB in the MZDI scheme[12], this scheme have the SR of 10 dB.

3 Conclusion

We proposed an AOSPC based on SLALOMs and the 10-bit converter for 80Gb/s RZ optical signal verified the scheme feasibility. The pattern effects and ASE noise in SOA degrade the performance and affect the optimum optical power values of the signal and control pulses. A certain delay of the control pulse relative to the signal pulse benefits the performance improvement. The difference of receive sensitivity for each output signal should be further reduced in the future study.

References

[1] WEBER H G, LUDWIG R, FERBER S, *et al*. Ultrahigh-speed OTDM-transmission technology [J]. *Journal of Lightwave Technology*, 2006, **24**(12): 4616-4627.

[2] GNAUCK A H, CHARLET G, TRAN P, *et al*. 25. 6-Tb/s WDM Transmission of polarization-multiplexed RZ-DQPSK signals[J]. *Journal of Lightwave Technology*, 2008, **26**(1): 79-84.

[3] MORIOKA T, TAKARA H, KAWANISHI S, *et al*. 1 Tbit/s (100 Gbit/s × 10 channel) OTDM/WDM transmission using a single supercontinuum WDM source[J]. *Electronics Letters*, 1996, **32**(10): 906-907.

[4] ZHANG Li-tai, YU Jin-long. Research on high-speed all-optical signal processing based on semiconductor optical amplifier[D]. Tianjin: Tianjin University, 2008.

[5] WANG M, WU J, XU K, *et al*. All-optical serial-to-parallel converter for simultaneous multiple-channel OTDM demultiplexing[J]. *Electronics Letters*, 2009, **45**(9): 474-475.

[6] WEN Jiang-hong, JIANG Yang, LUO Xuan, *et al*. All-optical serial-to-parallel conversion based on four wave mixing effect in fiber[J]. *Journal of Applied Optics*, 2011, **32**(3): 535-538.

[7] WU Zhi-lin, YAO Min-yu, GAO Yi-zhi, *et al*. 4×2. 5 GHz OTDM demultiplexing using SLALOM[J]. *Chinese Journal of Lasers*, 1998, **25**(1): 77-80.

[8] HU Hao, YU Jin-long, ZHANG Li-tai, *et al*. 40-Gb/s all-optical serial-to-parallel conversion based on a single SOA[J]. *IEEE Photonics Technology Letters*, 2008, **20**(13): 1181-1183.

[9] TAKAHASHI R, YASUI T, SEOET J K, *et al*. Ultrafast all optical serial to parallel converters based on spin polarized surface-normal optical switches[J]. *IEEE Journal* on *Selected Topics in Quantum Electronics*, 2007, **13**(1): 92-103.

[10] YU Jin-long, LUO Jun, WANG Wen-rui, *et al*. Scalable optical serial to parallel converter based on prechirped pulse probe and cross-phase modulation in fiber[J]. *Microwave and Optical Technology Letters*, 2011, **54**(9): 2108-2110.

[11] YU Jin-long, HU Hao. A scheme of novel all-optical serial-to-parallel conversion applied to high speed optical packet switching: China, 200610014404. 1[P]. 2006-12-6.

[12] KUSANO H, UEMOHARA H. Silicon photonic optical serial-to-parallel converter with phase operation [C]. European Conference on Optical Communications, 2013, paper h2. B. 3.

[13] EISEL T M, PIEPER W, WEBER H G. SLALOM: Semiconductor laser amplifier in a loop mirror[J]. *Journal of Lightwave Technology*, 1995, **13**(10): 2099-2112.

[14] SHI Han-xing. Performance analysis on semiconductor laser amplifier loop mirrors [J]. *Journal of Lightwave Technology*, 2002, **20**(4): 682-688.

[15] KANE M G, GLESK I, SOKOLOFF J P, *et al*. Asymmetric optical loop mirror: analysis of an all-optical switch [J]. *Applied Optics*, 1994, **33**(29): 6833-6842.

[16] PAUL T, ROBERT R J, GLESK I, *et al*. Comparison of three nonlinear interfereometric optical switch geometries[J]. *Optics Communications*, 2000, **175**(4-6): 365-373.